REMARKS

Claims 1-20 are pending in the present application. By this timely filed response, Claims 1, 3, 9, 10, 11, 12, & 13 are amended, Claims 2 and 4 are cancelled, FIGS. 1, 2, 4, & 7 are amended, FIG. 5(c) is added, and paragraph [0054] of the specification is amended to now include reference to FIG. 5(c). No new matter is presented in this response.

I. INFORMATION DISCLOSURE STATEMENT.

The Examiner requested the submission of a Supplemental IDS that includes all non-patent literature, published applications, or patents authored by any of the inventors that relate to the claimed invention. The Examiner also requested that the Applicants submit a copy of any literature cited as a reference in documents described above that relate to the claimed invention. Applicants have included a Supplemental IDS along with several documents in this response, however, the new references are not believed to be material to the patentability of the present invention.

II. INVENTORSHIP

In paragraph 2 of the office action, the inventorship of the present application was questioned as noted below.

> 2. In view of the subject matter found in the Examiner-discovered thesis of Xie cited above, and the statements regarding the contribution of the other co-inventors in the "Acknowledgements" section of the thesis, the contribution of co-inventors to the claimed invention is questioned.
>
> Applicant is requested to review the contribution of each inventor in relation to the *claimed* invention to confirm whether proper inventorship is claimed. As further evidence, the subject matter shown in Figure 5B of the application is shown in Figure 2 of "A Single-Crystal Silicon 3-Axis COMS-MEMS Accelerometer", IEEE Sensors, 2004, authored by only one of the present applicants, as well as two authors not listed as applicants.

As requested by the Examiner, the Applicants have thoroughly reviewed inventorship in the present application. The Applicants have confirmed that the inventorship as filed is legally proper. The tri-axial micromachined accelerometer embodied in Claims 1-20 of the present Application was conceived as a result of collaboration between all four named inventors. The collaboration stemmed from a research project between Carnegie Mellon University (CMU) and the Robert Bosch Corporation (Bosch) that began in 2000 and continued through the filing of Provisional application No. 60/449,745 on February 24, 2003. During the relevant timeframe Dr. Pan and Dr. Frey were researchers at Bosch who collaborated with Dr. Fedder and Dr. Xie on the research project. During the development of the tri-axial micromachined accelerometer of Claim 1, Dr. Fedder, a professor at CMU, was Dr. Xie's advisor for his doctorial thesis. Dr. Xie also worked closely with Dr. Pan and Dr. Fry while working as intern at Bosch during the summer of 2001. As a result of the collaboration, the Bosch inventors each contributed to *at least* the subject matter recited in claims 6 and 8.

Applicants note that the Xie Ph.D. thesis (hereafter the "Xie Thesis") cited by the examiner is entitled "*Gyroscope* and Micromirror Design Using Vertical Axis CMOS-MEMS Actuation and Sensing". The subject matter disclosed in the Xie Thesis is almost exclusively related to gyroscopes, which are quite distinct devices having distinct structures as compared to accelerometers. Gyroscopes measure rotation through actuation, as opposed to accelerometers which *sense* acceleration without actuation. The SEM of the circuit shown in Fig. 6-38 on page 194 of the Xie Thesis (cited by the Examiner) is the only disclosure therein which relates to accelerometers. As can be seen from the below copy of page 194 of the Xie Thesis relating to Fig. 6-38 provided below, no details regarding the accelerometer are provided or can be discerned from the image other than that there is a structure shown alongside the three single axis gyroscope chips labeled "3-axis accelerometer".

A single-chip, six-degree-of-freedom, integrated IMU has been designed and fabricated jointly with Robert Bosch Corporation. A scanning electron micrograph (SEM) of the device is shown in Fig. 6-38. Further mechanical characterization and more reliable interface circuit design are undergoing.

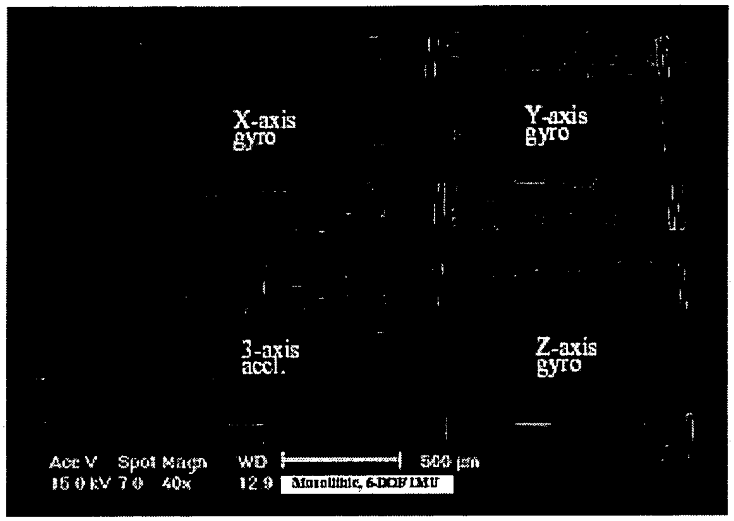

Figure 6-38: SEM of a released 6-DOF IMU.

Since the Xie Thesis relates almost entirely to gyroscopes and only provides an image of a 3-axis accelerometer and the non-descriptive information copied above, the Xie Thesis is not relevant to inventorship, nor to the patentability of the claimed invention as described more fully below. This explains why Applicants did not submit the Xie Thesis in their IDS filing.

The 2004 IEEE paper does not evidence improper inventorship either. Although, unlike the Xie Thesis, the 2004 IEEE paper relates to 3-axis CMOS-MEMS accelerometers as does the present invention, authorship and inventorship are determined differently. As defined in patent law, an inventor is "a person contributes to the conception of the invention." *Fiers v. Revel*, 984 F.2d 1164, 1168; *MPEP* §2137.01. The 2004 IEEE paper, which was published one and a half years after the present application, does include two coauthors other than Dr. Xie. The 2004 IEEE paper describes a 3-axis accelerometer with a different design and a modified fabrication process compared to the present invention. Since the 2004 IEEE paper discloses a different 3-axis accelerometer and process when compared to the present invention, it does not evidence improper inventorship. Accordingly, Applicants submit that the four named inventors in the present application are legally the proper inventors.

III. DRAWINGS.

In the office action the Examiner requests corrections to several drawing to comply with patent law requirements. Pursuant to 37 C.F.R. 1.121(d), the Applicants have submitted drawings with the appropriate corrections highlighted in red for inspection and approval by the Examiner. The Applicants have also included new FIG. 5(c) for Examiner approval. No new matter has been added.

IV. AMENDMENT TO THE SPECIFICATION.

The Applicants have amended paragraph [0054] of the specification to insert figure references referring to new Fig. 5(c). These amendments do not contain new matter.

V. §112, PARAGRAPH 1 REJECTIONS.

In the office action, the Examiner asserts

> 9. Claim 11 is rejected under 35 U.S.C. 112, first paragraph, as failing to comply with the written description requirement. The claim(s) contains subject matter which was not described in the specification in such a way as to reasonably convey to one skilled in the relevant art that the inventor(s), at the time the application was filed, had possession of the claimed invention. The detailed description and/or drawings fail to depict or show how to fit x-y sensing structure inside the rigid frame while providing room and operability for the z-axis accelerometer.

Applicants note that paragraph [0054] of the specification as filed clearly describes the subject matter noted above in an enabling fashion to one having ordinary skill in the art. Applicants have added FIG. 5(c) to visually depict this subject matter, and amended paragraph [0054] to refer to new FIG. 5(c). No new matter is added by this amendment. Accordingly, Applicants respectfully request the Examiner withdraw the §112, paragraph 1, rejection of Claim 11.

VI. §112, PARAGRAPH 2 REJECTIONS.

Re Claim 1: The Examiner states that the phrase "single sensor," as recited in Claim 1, is unclear. The Examiner points out that there are distinct microstructure areas having different sensors. In response, Applicants have amended Claim 1 by modifying the phrase "single sensor microstructure" to read "single microstructure."

Re Claim 2: Applicants have cancelled Claim 2.

Re Claim 4: Applicants have cancelled Claim 4.

Re Claim 8: The Examiner states that it is unclear how Claim 7 is further limited by Claim 8. The discussion indicates the lack of clarity stems from use of the word "ones." Claim 8 is amended to eliminate the word "ones" and replace it with "sides." This clarifies that Claim 8 further limits Claim 7 by requiring that "respective *sides* of said comb finger sets are electrically isolated from one another."

Re Claim 9: The Examiner states that Claim 9 is unclear concerning how the rigid frame can structurally decouple xy-sensing from z-sensing. Claim 9 is amended to eliminate the phrase "for decoupling x-y sensing from z-sensing."

Re Claim 10: The Examiner states that Claim 10 is unclear concerning what the z-sensing elements are. Claim 10 is amended to add the clause "wherein said structure for z-sensing includes a proof mass disposed inside said rigid frame by at least one flexure for decoupling z-sensing from x-y sensing.," Applicants believe this modification clarifies what the z-sensing elements are and, per claim 9, how z-sensing is decoupled from x-y sensing.

Re Claim 11: The Examiner states that Claim 11 is unclear concerning how the x-y sensing structure can be an effective proof mass to z-sensing when the x-y sensing structure is decoupled from the proof mass. The Applicants amended Claim 11 to add the clause "wherein said structure for x-y sensing includes a proof mass disposed inside said rigid frame by at least one flexure for decoupling x-y sensing from z-sensing." The Applicants assert that this modification combined with FIG. 5(c) clarifies how the rigid frame plus the x-y sensing structure is an effective proof mass for z- sensing.

The Examiner then asserts that Claim 11 is an omnibus type claim on the basis that Claim 9 describes an embodiment a situation where the x-y sensing structure is outside the rigid frame

while the x-y sensing structure in Claim 11 is inside the rigid frame. The Applicants respectfully disagree with this characterization of Claim 9. Claim 9 does not state whether the x-y sensing structure is inside or outside of the rigid frame. In fact, Claim 9 requires only that there is a rigid frame "disposed between structure for x-y sensing and structure for z-sensing." It is apparent from the language of Claim 9, paragraph [0054], and FIGS. 5(a) & (c), that the x-y sensing structure can be inside or outside of the rigid frame. Therefore, Claim 11 is not an omnibus type claim since the language of Claim 9 allows for a 3-axis accelerometer with the x-y sensing structure inside or outside of the rigid frame.

Re Claims 12 and 13: The Examiner states that Claims 12 and 13 are unclear concerning what the structures for differential capacitive sensing sense and how the structure is related to the elements of parent Claim 1. Claim 12 was amended to delete "said accelerometer" and replace it with "at least one of said comb finger sets for motion sensing." Similarly, Claim 13 was amended to delete "accelerometer" and replace it with "comb finger sets for motion sensing." The amendments should clarify what is being sensed and how the sensing structures are related to the elements of Claim 1.

The Applicants submit that the modifications described above resolve all §112, paragraph 2 objections for all pending Claims, and request that the Examiner withdraw all §112, paragraph 2 objections.

VII. §102(a) Rejections.

The Office Action made the following rejection:

21. Claims 1-10 and 16-20 are rejected under 35 U.S.C. 102(a) as being anticipated by the Hukai Xie Ph.D. thesis of May 2002 (Reference W).

22. Figure 6-38 on page 194 of the thesis, taken in conjunction with the text of the thesis, clearly shows a three-axis accelerometer chip having a plurality of comb finger sets with one set for each of three orthogonal axes, where all are on a membrane layer portion of a single crystal substrate, and a proof mass support by at least one flexure, with comb fingers on the proof mass, where the flexure connects the proof mass to the membrane. A pre-

amplifier is shown on-chip in Figure 6-24 on page 126. The comb finger sets provide fully differential capacitive bridges for all axes, and are formed of metal/dielectric stacks disposed on the membrane layer, where the metal may be electrically connected or isolated from the membrane layer, with the membrane layer having a smaller cross-section than the metal area of the fingers (Figure 3-20, page 51; and Figure 6-37, page 194). The structure for Z-axis sensing is spring decoupled from a rigid frame used for supporting comb fingers for x- and y-axis sensing. The membrane layer is further taught as being less than 100um thick on page 18.

Before reviewing the cited art, Applicants will first review the claimed invention as now recited in amended claim 1. Amended Claim 1 recites a monolithic integrated 3-axis accelerometer chip, comprising a single crystal substrate that includes at least one single crystal membrane layer portion. The membrane layer is a layer which is suspended and anchored on the single crystal substrate. A single microstructure is formed using the single crystal membrane layer, the sensor microstructure capacitively sensing and providing acceleration data for all three orthogonal axes. The sensor microstructure comprises a plurality of comb finger sets including at least one comb finger set for motion sensing in each of the three orthogonal axes, the comb finger sets comprising a plurality of comb fingers. Each of the comb finger sets for each of the three orthogonal axes include the single crystal membrane layer. At least one electronic circuit is formed on the single crystal membrane layer for processing the acceleration data.

As noted in the background of Applicants' application (see paragraphs [0008] and [0009]), some MEMS 3-axis accelerometers were known prior to the filing of the application. For example, a paper by Lemkin et al. (submitted in the earlier filed IDS) discloses a surface micromachined 3-axis accelerometer [Lemkin, et al. "A 3-Axis Force Balanced Accelerometer

Using a Single Proof-Mass" Transducers '97, 1997 International Conference on Solid-State Sensors and Actuators, Chicago, June 16-19, 1997, pgs. 1185-1188]. Lemkin's accelerometer uses single-crystal silicon (SCS) as the substrate material, but the sensor microstructures built on the SCS substrate are made of thin-film polysilicon. The x- and y-axis sensing elements disclosed by Lemkin are comb fingers based on polysilicon, while the z-axis sensing capacitance is formed as a parallel plate pair between the proof mass and a ground polysilicon layer on the substrate. Thus, a separate fixed capacitor is used to realize a differential capacitive bridge for z-axis sensing. Significantly, the inherent large parasitic capacitance greatly reduces the obtainable signal-to-noise ratio. The residual stress of the thin-film materials also limits the size of the proof mass which limits the obtainable resolution of the Lemkin's accelerometer.

Amended Claim 1 integrates electronics with a 3-axis acceleration sensing microstructure which includes a single crystal membrane. The 3-axis accelerometer sensing microstructures uses comb fingers utilizing a single crystal membrane layer for x-, y- and z-axis capacitive acceleration sensing. Accordingly, the proof mass can be larger (e.g. more than 100 fold heavier than that of Lemkin), and provide much higher resolution. The single-crystal silicon microstructure of the present invention is robust and demonstrates good temperature performance.

The DRIE CMOS-MEMS process illustrated by FIGs. 1(A) –(D) is a key enabling technology that enables the fabrication of 3-axis accelerometers using a single crystal membrane layer as provided by the present invention. Figures 1(A)- (C) illustrate cross sections of intermediate structures, while FIG. 1(D) illustrates a cross section of a monolithic integrated single crystal silicon (SCS) microstructure obtained using a DRIE CMOS-MEMS process. Without such a process at the time of the invention, sensor microstructures based on a single

crystal membrane were not manufacturable, particularly when combined with on-chip electronic circuits for processing the accelerometer data.

Regarding Fig. 6-38 the examiner asserts that:

> 22. Figure 6-38 on page 194 of the thesis, taken in conjunction with the text of the thesis, clearly shows a three-axis accelerometer chip having a plurality of comb finger sets with one set for each of three orthogonal axes, where all are on a membrane layer portion of a single crystal substrate, and a proof mass support by at least one flexure, with comb fingers on the proof mass, where the flexure connects the proof mass to the membrane.

Applicants hospitably disagree with the above assertions regarding the Xie Thesis. As noted above, the Xie Thesis is entitled "*Gyroscope* and Micromirror Design Using Vertical Axis CMOS-MEMS Actuation and Sensing" and is almost exclusively related to gyroscopes and gyroscope enabling components (e.g micromirrors). Moreover, gyroscopes are clear quite distinct devices having distinct structures as compared to the accelerometers of the present invention. The only disclosure in the Xie Thesis which relates to 3-axis accelerometers is the SEM of the circuit shown in Fig. 6-38 and the accompanying four lines of text on page 194 cited by the Examiner. As can be seen from the above excerpt of page 194 of the Xie Thesis relating to Fig. 6-38, no details regarding the accelerometer are provided or can be discerned from the image other than the accelerometer on chip as being a "3-axis accelerometer". Accordingly, the entirety of the "text of the thesis" relied on by the Examiner, is primarily related to gyroscopes and micromirrors, except for the previously mentioned four lines of nondescript text mentioning an accelerometer.

From those four nondescript lines and the Fig. 6-38 image, it is not possible to determine whether the structure labeled 3-axis accelerometer is formed on a *single crystal substrate including at least one single crystal membrane layer portion.* From the very limited mention provided and looking at Fig. 6-38, it is equally impossible to determine whether *the sensor microstructure capacitively senses acceleration.* Similarly, since there is no disclosure concerning how the structure labeled three-axis accelerometer in Fig. 6-38 works, there is no way to know whether that structure capacitively senses acceleration. Thus, Applicants

respectfully submit that the assertions made by the Examiner based on the Xie Thesis are clearly not supported by the Xie Thesis. The claimed features of a "three–axis accelerometer chip having a plurality of comb finger sets with one set for each of the three orthogonal axes," where the comb finger sets for sensing in each of the three axes include the membrane layer, can only be found in the present Application.

Claimed features asserted by the Examiner to be disclosed by the Xie Thesis, such as the (i) plurality of comb finger sets with one for each of the three orthogonal axes, (ii) where all comb fingers are on a membrane portion of the single crystal substrate, and (iii) the fingers capacitatively sensing, are simply not discussed or suggested by the Xie Thesis. Therefore, amended claim 1 is patentable over the Xie thesis.

In the Conclusion section of the Office Action copied below, the Examiner cites other papers as being relevant to the claimed invention:

24. Most of the prior art cited generally shows CMOS process MEMS devices that show multilayer stacks of metal and dielectric for comb fingers, including lateral and/or vertical sensing, with fully differential sensing. Reference U' further teaches a 50um to 80um thick membrane layer, and no-chip preamplifier, metals stacks electrically connected and/or isolated from the membrane layer, where the membrane layer is smaller in cross-section than the stack. Reference U indicates in the introduction that interdigitated comb fingers can be used for displacement or acceleration detection in all three directions, and that integrated tri-axial accelerometers have such advantages as smaller size and less cost than the combination of three discrete single-axis accelerometers.

As discussed below, references U and V are not related to the present claimed invention because they disclose single axis accelerometers based on thin-film (**not** single crystal membrane) technology. Reference U is an IEEE paper by Xie et al. entitled "A CMOS Z-axis Capacitive Accelerometer with Comb Finger Sensing" that was published in 2000. This paper

discloses a thin-film microstructure approach that senses z-axis acceleration using comb fingers. Although the accelerometer reported in reference U is based on MEMS and discloses comb finger sensing, the sensor microstructure uses thin-film layers, not the single-crystal membrane layer utilized by the comb finger sensors of the claimed invention. Furthermore, while the possibility of 3-axis accelerometers is mentioned in reference U, the discussion is limited to thin-film microstructures, not the single crystal membrane layer approach of the present invention.

Reference V is a paper by Zhang et al. entitled "A Lateral Capacitive CMOS Accelerometer with Structural Curl Compensation" that was published in 1999. Like reference U, this accelerometer is single-axis. Although reference V is based on MEMS and discloses comb finger sensing, the sensor microstructures are metal/oxide composite thin-film layers, not the single crystal membrane layer–based microstructures of the claimed invention.

Several dependent claims a believed to recite independently patentable features. For example Claim 8 recites comb finger sets where each side is electrically isolated from the other. Claim 9 recites a rigid frame that is disposed between the structure for x-y sensing and the structure for z-sensing. Another example is Claim 10, which builds on Claim 9 by reciting a structure where the proof mass for z-sensing is disposed inside the rigid frame by at least one element for decoupling z-sensing from x-y sensing. Similarly, Claim 11 is dependent on Claim 9, reciting a structure where the proof mass for x-y sensing is disposed inside the rigid frame by at least one element for decoupling x-y sensing from z-sensing. Finally, Claims 18 and 19 recite instances where the cross sectional area of the membrane layer is less than the cross sectional area of the metal/dielectric stack thereon. None of these claimed features recited in Claims 8-11, 18 and 19 are disclosed or suggested in the cited art, whether alone or in combination.

Applicants have made every effort to present claims which distinguish over the cited art, and it is believed that all claims are now in condition for allowance. However, Applicants request that the Examiner call the undersigned (direct line 561-671-3662) if anything further is required by the Examiner prior to issuance of a Notice of Allowance for all claims.

Respectfully submitted,

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